BUG ALGORITHM TO GUIDE WHEELCHAIR MOTION BASED ON OFFLINE ELECTRO-OCULOGRAPHY SIGNAL

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To my beloved father, mother, wife, son, and daughter.

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ABSTRACT

Certain disabled persons are not able to control the common powered wheelchair using joystick due to their limb movement restrictions. Hence, lots of current researches have studied other alternatives to control the powered wheelchair. Electrooculography (EOG) eye tracking control is one of the most ordinary alternative means to control the wheelchair because it offers a more natural mode to guide the wheelchair. Yet, it cannot be realized because users are normally not allowed to look around the surrounding environment during wheelchair motion. This is because the eye movements control the wheelchair while the user needs to look up to move forward, right to turn right, left to turn left and down to stop the wheelchair. In addition, this method exhausts the user due to the concentration needed during the navigation process. In this study, an automatic navigation approach alongside the manual method is proposed to guide the wheelchair by means of offline EOG signal. The automatic mode navigates the wheelchair from initial point to goal point while avoiding obstacles by employing Bug2 algorithm. Bug algorithms guide the robot from its starting point towards a preset goal point and avoid obstacles detected by sensors, and they do not require any other information about the environment in the navigation process. The EOG signals are measured, recorded, and analyzed using a biomedical measurement system (KL-720). The desired goal point direction and distance are calculated by analyzing horizontal and vertical gaze angles obtained. The hardware of the powered wheelchair is developed and modified so that it can be controlled automatically using EOG signal. The simulation done showed that Bug algorithms are able to guide the wheelchair to the desired destination based on only EOG signal. The new technique allows the user to look around without restraints, while the wheelchair is navigated automatically to the desired goal point.

ABSTRAK

Orang-orang kurang upaya yang tertentu tidak dapat mengawal kerusi roda berkuasa biasa menggunakan kayu bedik kerana kekangan pergerakan anggota badan mereka. Oleh itu, banyak kajian semasa telah mengkaji alternatif lain untuk mengawal kerusi roda berkuasa. *Electrooculography* (EOG) mata kawalan pengesanan adalah salah satu kaedah alternatif yang paling biasa untuk mengawal kerusi roda kerana ia menawarkan cara yang lebih semulajadi untuk mengawal kerusi roda. Namun, ia tidak boleh dicapai kerana pengguna biasanya tidak dibenarkan melihat persekitaran semasa gerakan kerusi roda. Ini adalah kerana pergerakan mata mengawal kerusi roda ketika pengguna perlu mencari untuk bergerak ke hadapan, kanan untuk belok kanan, kiri untuk belok kiri, dan ke bawah untuk menghentikan kerusi roda. Di samping itu, kaedah ini meletihkan pengguna disebabkan oleh konsentrasi yang diperlukan semasa proses navigasi. Dalam kajian ini, pendekatan navigasi automatik di samping kaedah manual dicadangkan untuk mengawal kerusi roda dengan cara isyarat EOG secara tidak atas talian. Mod automatik melayari kerusi roda dari titik awal ke titik matlamat dengan mengelak halangan menggunakan Bug2 algoritma. Algoritma-algoritma Bug membimbing robot dari titik permulaan ke arah satu titik matlamat pratetap dengan mengelak halangan dikesan oleh sensor, dan mereka tidak memerlukan apa-apa maklumat lain mengenai keadaan sekeliling dalam proses navigasi. Isyarat EOG diukur, direkodkan dan dianalisis dengan menggunakan sistem pengukuran bioperubatan (KL-720). Arah matlamat yang dikehendaki dan jarak dikira dengan menganalisa sudut-sudut pandangan yang diperolehi. Secara mendatar dan menegak. Perkakasan kerusi roda berkuasa dibangunkan dan diubahsuai agar ia dapat dikawal secara automatik menggunakan isyarat EOG. Simulasi yang telah dilakukan menunjukkan bahawa algoritma Bug dapat mengawal kerusi roda ke destinasi yang dikehendaki hanya berdasarkan isyarat EOG. Teknik baru ini membolehkan pengguna melihat sekeliling tanpa sekatan, manakala kerusi roda bergerak secara automatik ke titik matlamat yang dikehendaki.

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LIST OF ABBREVIATIONS

NFIC	-	New Freedom Initiative Act
ALS	-	Amyotrophic Lateral Sclerosis
EMG	-	Electromyography
EOG	-	Electrooculography
EPW	-	electric-powered wheelchair
IR	-	Infrared
EEG	-	Electroencephalography
BCI	-	brain-computer interfaces
HCI	-	Human Computer Interfaces
ECG	-	Electrocardiogram
ERG	-	Electroretinogram
CSV	-	Comma Separated Values
GUI	-	graphical user interface
PWM	-	pulse-width modulations
USB	-	Universal Serial Bus
CW	-	clockwise rotation
CCW	-	counterclockwise rotation
GND	-	Ground
IRED	-	Infrared Emitting Diode
PSD	-	Position Sensitive Detector

CHAPTER 1

INTRODUCTION

1.1 Project Background

The New Freedom Initiative Act (NFIC) approximated that, aged and disabled individuals whom necessitate for wheelchair are more than 100 million global. The common powered wheelchairs; that are guided using joystick, are not handy for the disabled with limb movement restrictions such as spinal cord injury and amyotrophic lateral sclerosis (ALS). Hence, an alternative approaches are investigated to help those disabled and elderly who cannot use the manual powered wheelchair. These alternative approaches concentrated on guiding the wheelchair by means of other body signals and other body parts that are not defected.

Among the guiding approach substitutes are: controlling a wheelchair by means of head gestures suggested by Wei (2004), (Matsumotot *et al.*, 2001), Nakanishi *et al.* (1999) and Kuno *et al.* (2001); guiding by means of voice recognition by (Levine *et al.*, 1999; Cagigas and Abascal, 2004); a guide based on the Electromyography (EMG) signal proposed by Felzer and Freisleben (2002) and Moon *et al.* (2005); and Electrooculography (EOG) eye tracking control presented in the literature by Mazo (2001).

1.2 Problem Statement

The EOG eye tracking guide presents a more likely and natural manner to control the wheelchair. Still, it is neglected, for the reason that the wheelchair user is not capable to look or gaze at the nearby atmosphere throughout the navigation route, which is very exhausting for the user's eyes. Hence, several researchers such as Hashimoto *et al.* (2009) and Tsui *et al.* (2008) attempted to rise above this difficulty by utilizing the EMG signal, which control direction; in addition to the EOG signal, which control speed to guide the wheelchair. In this research, the powered wheelchair is guided by means of eye gazes and blinks. Bug algorithm is utilized to navigate the wheelchair automatically to the desired goal point.

1.3 Objectives

This study aims to assist those people with serious disabilities to advance their mobility and substantially enhance their living quality. The main objective of this study is to guide the wheelchair motion based on EOG signal. Yet, the wheelchair user will be able to look around and surround, due to the hands-free control system that uses only eyes gaze and blinks to control the powered wheelchair. For this to be achieved, the following objectives need to be attained:

1. Develop powered wheelchair hardware and software, which can be controlled based on EOG signal.

2. Record, and analyze eye movements by means of the EOG signal measurement system.

1.4 Scopes of Study

A wheelchair motion guide based on EOG signal is a recent study topic. EOG offers a lot of possibilities and functions beside the wheelchair motion guide is a promising research area. The scope of this study contains:

1. Review on powered wheelchairs and approaches used to control them, including EOG signal which is applied in this study. The EOG signal used in this research is offline signal.

2. Study and compare path finding algorithms including Bug algorithms, which are implemented in our project. Bug2 and Tangent-Bug are simulated, and the wheelchair is guided automatically by means of Bug2 algorithm.

3. Development of the automatic wheelchair's hardware, and software. Hardware includes sensors, motor drivers, rotary encoder, microcontroller, and the interface among these parts with the wheelchair. While software includes programming the microcontroller to read all inputs and also to utilize the Bug algorithm.

4. Investigate the eye movement tracking and recording based on the EOG signal measurement system. Also, utilize the gaze angles and blinks measured to control the wheelchair automatically and manually.

1.5 Project Significance

A new automatic controlling method is introduced beside the common manual method. In the automatic controlling mode, the user gazes at the desired destination, then blink to send the signal to the wheelchair to start navigating. Bug2 algorithm is utilized to control the wheelchair in automatic guide mode.

This work is conducted especially to rise above the drawback of the typical powered wheelchair controlled based on EOG signal. The user can enjoy looking at the neighboring environment freely during the wheelchair motion process.

1.6 Thesis Organization

After acknowledging the requirement to fulfill the perception of this study, this thesis has been written and accumulated with the optimum effort in terms to attain the ease of the reader. This report includes six chapters with the brief outline of each chapter as stated as follows:

Chapter 1 serves as an introduction to this research; it includes the background of the project, problem statements, objectives of the research, and scopes of the study.

After that, Chapter 2 provides literature reviews from previous research work from other researches on powered wheelchair motion guides, path finding algorithms and EOG signal.

And Chapter 3 has been utilized to explain and discusses the methodology applied in this project, including the project planning and measurements of EOG signal ; the hardware, and software of the wheelchair; as well as calibration and development of the controlling method based on Bug2 algorithm.

In Chapter 4, the findings and simulation of this project are demonstrated and examined together with the indication to strengthen the results of the study.

The last chapter, particularly Chapter 5 ceases the entire contents of this thesis and provides the conclusions and recommendations on researches that may be directed at the time ahead.

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